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Dissociated time course of recovery between strength and power after isoinertial resistance loading in rugby union players.

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ABSTRACT

There is a substantial amount of research on the responses to isometric and eccentric loading. However, only a paucity of literature exists on the responses to isoinertial loading, especially in trained athletic populations using realistic loading protocols. The purpose of this study was to examine the acute neuromuscular response to a bout of isoinertial resistance loading in elite rugby players. Seventeen male (age: 19.5 ± 2.3 years) academy rugby union players performed a conventional maximal isoinertial resistance loading protocol. Countermovement jump (CMJ) and maximal voluntary isometric squat (MVC) performance was measured on three occasions: at baseline, immediately post and 48h post. The results indicated that the decrease in MVC (9.7%) is greater than or comparable with the CMJ output variables (4.2-10.3%), immediately post exercise. Whilst isometric strength had demonstrated a full recovery at 48h post, many of the key CMJ output variables were still impaired ($P < 0.05$). Similar findings were observed in the normalised CMJ curves. Complete recovery of the ability to rapidly produced force may require more than 48h in many athletes. Individual responses should therefore be monitored to help plan acute and chronic training loads. It is recommended that future fatigue studies should incorporate temporal phase analyses to consider the power-, force-, velocity-, and displacement-time curves.

Keywords: athletes, resistance training, rest, sports

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INTRODUCTION

Resistance training sessions require the interaction of many regulatory systems within the body. The neuromuscular system is however of particular interest when consideration is given to fatigue induced changes in force production. Neuromuscular fatigue (NMF) is a complex phenomenon and is described as an exercise induced decrease in the maximal force capabilities of a muscle or muscle group, regardless of whether or not a given task can be maintained (8). The cause of fatigue is regarded as multifactorial, with the proportion attributed to central and peripheral mechanisms being influenced heavily by the characteristics of the task (22).

A variety of loading protocols using isometric (7) or eccentric (31) contractions have been used in many of the classic fatigue studies. However, there are relatively few studies that have investigated NMF in response to isoinertial resistance loading (i.e. constant resistance to motion) (49), which is somewhat surprising given the large volume of literature that have considered the chronic adaptations to such resistance training programmes (17). The proven relationship between training load and performance will naturally encourage progressively higher volumes of training in an attempt to realise the small, but often competition defining results (21). It therefore seems reasonable to infer that a better understanding of the acute NMF induced from such training would help strategically manage the daily training load of an athlete. Athletes typically spend the majority of their time recovering from bouts of training, so establishing the appropriate time interval is viewed as a vital component to both optimise subsequent training and also to avoid overtraining.

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In functional terms, NMF induced by isoinertial resistance loading has typically been quantified using maximal voluntary isometric contraction (MVC) tests (10). Previous studies have demonstrated that MVC is reduced immediately after exercise as expected and then recovers toward initial levels over the ensuing days (3-5, 9, 26, 30, 32, 43, 44). When the contractile properties are sampled at frequent intervals, the fatigue pattern is likely to take place in a bimodal fashion (42), especially when the protocol is exhaustive enough (37). In this regard, MVC determines the volitional force generating capacity of a muscle under stable conditions and can be considered to be a valid gauge of any functional impairment (20). Whilst the fatiguing effects of isoinertial resistance loading appear to be relatively well established within the literature, the majority of these studies have used hypertrophy orientated protocols (3-5, 9, 30, 43), excessive volumes of high intensity loading (32) or used recreationally trained subjects (44). Fatigue is highly specific (3, 32) and there is a clear dearth of literature investigating the acute response to maximal isoinertial resistance loading utilising multi-joint exercises in trained athletic populations. This type of training is characterised as high intensity (80-100% 1RM), low volume (3-5 sets of 3-5 repetitions) with extended (3-5 min) rest periods between sets.

Although maximal strength is an important quality in many sports, it is also important to note that it takes 400–600 ms to reach peak force from the onset of a maximal isometric contraction (2). This is in stark contrast to the time frames that occur during many sports activities such as sprinting and kicking, where contraction times are often <250 ms, meaning that peak force capabilities may not be realised. As a consequence, fatigue induced reductions in rapid force production are likely to impair the capacity to perform many explosive sporting movements and increase the risk of injury. The ability to rapidly develop force may therefore constitute a critical functional measure of NMF. A countermovement jump (CMJ) reflects the

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natural occurring stretch-shortening cycle (SSC) used within most sports (37) and as such, represents the most common dynamic performance measure of NMF induced by isoinertial resistance loading (9, 26, 42, 44). The development of an high level of active state during the eccentric phase regulates SSC function and therefore CMJ performance (15, 16), which has been typically described by a discrete variable such as jump height (23). Thus the standard methodology used to analyse CMJ performance invariably disregards large amounts of data. A more comprehensive analysis of power, force, velocity and displacement curves (13, 14) throughout the entire jump may provide additional insight. Collectively, the small body of current literature suggests that the time course of recovery for MVC and CMJ may be mediated by different mechanisms. When compared to substantial impairments in MVC after isoinertial loading, jump height has either showed no change (26), slower recovery (44) or a faster recovery (9) during the 24, 48 and 84h recovery periods used, respectively. Thus, the aim of this investigation was to examine the acute neuromuscular response to a bout of maximal isoinertial resistance loading in a trained athletic population. Specifically, we examined how MVC and CMJ performance change to determine the magnitude and time course of exercise induced fatigue.

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METHODS

Experimental Approach to the Problem

The present study involved a repeated measure, cross-sectional research design to examine the acute neuromuscular response to maximal isoinertial resistance loading, as typically used within professional rugby union to improve power production by increasing the force component. The dependent variable assessed was the NMF response to the loading; derived from a MVC (peak net force) and CMJ performance (12 kinetic and kinematic variables).

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Subjects

Seventeen elite male rugby union players volunteered to take part in the study (age 19.5 ± 2.3 years, height 182.2 ± 6.5 cm, and mass 94.3 ± 12.2 kg). The study was conducted during a preseason training block. All the players were free from injury during the time of testing. Prior to the study commencing, the players attended a presentation to outline the purpose, benefits, risks and procedures involved in the study. Players provided written informed consent and were free to withdraw from the study at any stage without penalty. The study was approved by the Ulster University Human Research Ethics Committee.

Procedures

The testing and loading procedures were preceded by a standardised 10 minute warm-up period that consisted of jogging and dynamic stretching. A baseline measurement of CMJ and then MVC performance were taken immediately before the start of the resistance loading protocol, at approximately 0700 hours. The protocols used for both tests have been well described with the literature (39, 46). Three trials were used during each test, with the average used for further analysis. Subjects were asked to refrain from strenuous exercise for 48h before baseline testing and not to alter any aspect of their diet during experimental period. Subsequent measures were taken under the same conditions immediately post exercise and finally, at 48h post baseline.

Loading Protocol. The back squat exercise was selected as its efficacy has been repeatedly demonstrated in many training studies, to improve physical performance and also to reduce to injury risk (29, 47). A standard 20 kg Olympic barbell and plates (Eleiko AB, Halmstad,

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Sweden) were used for loading. Subjects squatted to parallel (the inguinal fold is level with the top of the knee musculature) using an appropriately dimensioned adjustable box to provide kinaesthetic feedback when depth was achieved and thus standardise the range of motion on every repetition. After a general warm-up and baseline testing, two sets of squats were performed at an intensity that corresponded to a perceived exertion rating of somewhat hard (33), this served as specific preparation before the loading protocol. The maximal strength protocol consisted of a 5,4,3,5,4,3 repetition wave pattern, with the load therefore varying in an undulating manner over the sets, as outlined by Wardle and Wilson (50). A percentage of the repetition maximum load was used to guide the initial set (85% 1RM), based on a 1RM completed at the beginning of the training block, with a desired perceived exertion of maximal sought on the remaining sets. Subjects were provided with strong verbal encouragement to ensure that the prescribed numbers of repetitions were competed and as a safety precaution, two spotters were provided on every set. This method resulted in a range of loads from 123 ± 19 kg in the first set to 131 ± 19 kg on the final set, with a total volume of 3024 ± 447 kg lifted. No participant failed a squat at any stage during the protocol. The tempo for each repetition was two seconds on the eccentric phase and an intention to move as quickly as possible on the concentric phase. A rest period of five minutes was given between sets.

Vertical Jump. CMJ trials were performed on a force plate (Kistler type 9286BA, Winterthur, Switzerland) that was connected to an A/D convertor (Kistler type 5691A1, Winterthur, Switzerland). Temporal and vertical ground reaction force (F_z) data were collected at a sampling frequency of 1000 Hz for 5 seconds using Bioware® software (Version 5.1, Type 2812A). The force plate was zeroed immediately before each trial and sampling began when the participant was standing still. After approximately 2 seconds, subjects were instructed to

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keep their hands on their hips and to jump as high as possible using a self-determined countermovement depth. Each participant completed 3 CMJ trials with 1 minute of rest in between, with the average used for further analysis. The F_z data were not filtered, as it has been reported as a potential source of error when determining jump height with the impulse method (46). The subjects' body weight was calculated as the average F_z during the first second of the sampling period. The first time the F_z deviated above or below body weight by more than 1.75 times the peak residual force found during the 1 second body weight averaging period was identified. A backward search was then completed until F_z passed through body weight, this time point was defined as the start of the countermovement. The take-off and landing time points were determined by finding the 0.4 second moving average with the smallest standard deviation F_z and then taking the peak residual force during this phase as the threshold (46). The vertical velocity of the centre of mass (COM) was determined using the impulse method. Net impulse was obtained by integrating net F_z using the trapezoid method from the start of the countermovement and then dividing it by body mass to obtain vertical velocity. Vertical displacement was subsequently determined by integrating velocity. Power was calculated as the product of F_z and velocity. The eccentric and concentric phases were defined as: eccentric phase, the start of the countermovement to minimum displacement (i.e., zero velocity); concentric phase, minimum displacement to the point of take-off. The vertical velocity of the COM at take-off was used to calculate jump height, as previously outlined (9). CMJ output (23) was defined as peak and mean values from the concentric portion of the jump.

In addition to the instantaneous CMJ variables, temporal phase analyses of the jumps were conducted using the method proposed by Cormie et al. (13, 14). The power-time and force-time curves were selected from each individual participant from the start of the jump to the

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take-off time point. The velocity-time and displacement-time curves were selected from the start of the jump to the apex of the jump (i.e., zero velocity). The number of samples in each individual curve was then modified to equal 500 samples by appropriately changing the time interval between samples and resampling the signal. The normalised curve for each sample was then averaged across all subjects, resulting in high resolution (477 - 640 Hz) power-, force-, velocity-, and displacement-time curves. This procedure allowed for power, force, velocity and displacement throughout the jump to be compared across baseline, immediately post and 48h post.

Maximal Strength. Isometric squats were performed in a custom built power rack that allowed the bar to be fixed in a horizontal position using pins positioned at 2.5 cm increments. The rack was positioned directly over a force plate (Kistler type 9286BA, Winterthur, Switzerland) that was connected to an A/D converter (Kistler type 5691A1, Winterthur, Switzerland). The desired position for testing required the subjects to stand on the force plate with their feet shoulder width apart, trunk near-vertical, internal knee angle of 90˚ and the immoveable horizontal bar placed above the posterior deltoids at the base of the neck. This position was established before each trial, with the joint angle determined using goniometry. Temporal and vertical ground reaction force (F_z) data were collected at a sampling frequency of 1000 Hz for 3 seconds using Bioware® software (Version 5.1, Type 2812A). The force plate was zeroed immediately before each trial and sampling began on verbal command. Subjects were instructed to push as hard and as fast as possible. After 3 submaximal efforts, each participant completed 3 maximal effort trials with 3 minute of rest in between. Peak net force expressed relative to body mass was obtained, with the average across trials used for further analysis. All subjects were given strong verbal encouragement during each trial.

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Statistical Analysis

Pearson's product moment correlation coefficient (*r*) was calculated to determine the association between MVC and CMJ output variables at baseline and also the percentage changes in MVC and CMJ at each of the post baseline time points. In addition, the coefficient of determination (r^2) was calculated to determine the explained variance between tests. Correlations were categorized using the following descriptors: <0.1 = trivial, <0.3 = small, <0.5 = moderate, <0.7 = large, <0.9 = very large, and ≥0.9 = extremely large (25). Thomas & Nelson (48) have indicated that when the common variation is less than 50%, the variables should be considered specific qualities and independent of each other. A general linear model repeated measures ANOVA was used to examine the impact of fatigue on performance variables. Mauchly's test of sphericity was applied and if violated, the Greenhouse-Geisser correction factor was used. Where appropriate, post-hoc analyses of significant effects were performed using the Bonferroni method. Statistical significance was set at $P \leq 0.05$ and the results summarised as mean ± SD. To improve the applicability of research to practice, the magnitude of change relative to the baseline time point was examined using the effect size (ES) statistic. The following magnitude thresholds were used: ≤0.2 = trivial, <0.5 = small, <0.8 = moderate, and ≥0.8 = large (12). All statistical calculations were performed using IBM SPSS Statistics 22 software (SPSS Inc., Chicago, IL, USA).

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RESULTS

The isometric squat test had moderate-large correlations with the CMJ output variables (r = 0.526 – 0.705). The coefficients of determination indicated that these tests are however largely independent (27.6 – 49.7% explained variation). No significant correlations were observed between changes (%) in isometric squat performance and the associated change in CMJ output variables at the immediately post and 48h post time points (Table 1). Isometric strength changed across the resistance loading protocol (F = 36.2; P < 0.001; Figure 1). Post hoc tests analysis showed a significant decrease in performance immediately post compared to baseline (17.0 ± 3.0 $N \cdot kg^{-1}$ vs. 15.3 ± 2.9 $N \cdot kg^{-1}$; P < 0.001; ES = 0.6) and recovery thereafter at 48h post (17.0 ± 3.0 $N \cdot kg^{-1}$ vs. 16.9 ± 2.9 $N \cdot kg^{-1}$; P > 0.05; ES = 0.0).

*****TABLE 1 NEAR HERE*****

*****FIGURE 1 NEAR HERE*****

Most CMJ variables showed significant decrements in performance immediately post compared to baseline, with the exception of average eccentric power and minimum displacement (Table 2). Moderate effect sizes (ES = 0.6) were noted for the following variables at this time point: average concentric power, peak eccentric power, peak eccentric force and minimum eccentric force. At 48h post, all force variables, peak eccentric power and minimum velocity had recovered to baseline levels. Countermovement jump performance variables with significant differences demonstrated an F = 6.9 - 25.1 (P < 0.05).

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*****TABLE 2 NEAR HERE*****

Significant differences between baseline and both immediately post and 48h post existed during the following phases of the CMJ curves: (a) power: 83.8% to 93.6% of normalised time; (b) velocity: 57.5% to 62.7% of normalised time; (c) displacement: 69.3% to 100% of normalised time. Significant differences between baseline and immediately post existed during the following phases: (a) power: 84.8% to 94.0% of normalised time; (b) displacement: 82.0 % to 100.0 % of normalised time (Figure 2). Phases of the normalised countermovement jump curves with significant differences demonstrated an F = 3.5 - 30.9 (P < 0.05; ES = 0.2-0.9).

*****FIGURE 2 NEAR HERE AS A 2 X 2 MATRIX*****

DISCUSSION

In the present study, we have investigated the magnitude and time course of recovery between MVC and CMJ performance after maximal isoinertial resistance loading. The main findings were that although the magnitude of changes in MVC and CMJ performance at 24 h were similar, they were not significantly correlated, suggesting that the relationship between these variables during the initial phase of recovery can be considered independent and governed in a unique physiological manner (Table 1). Furthermore, this perspective was supported when we consider the faster recovery of MVC at 48h (Figure 1) when compared to CMJ output variables such as peak concentric power or jump height (Table 2). The dissociated time course of recovery has many direct implications for athlete training.

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Several previous studies have investigated the relationship between relative isometric strength and CMJ output. These studies (24, 39, 45) have however consistently failed to establish any significant relationships. Such conflicting results with the current study may to some extent be related to the validity of the joint angle chosen during these multi-joint isometric tests (36). Nonetheless, the results from the present study suggest that although large correlations exist between isometric squat and CMJ output variables, the common variation was only 27.6 - 49.7%. These qualities can therefore be considered relatively independent and as such, regulated by different physiological mechanisms (6). Establishing this relationship at the outset is important when considering the magnitude and time course of fatigue (35, 41). Our results indicate that the decrease in MVC (9.7%) is greater than or comparable with the CMJ output variables (4.2-10.3%). Previous research (9) showed similar but nonetheless larger effects; however, the loading protocol used does not reflect common practice within professional rugby union. Furthermore, no significant correlations were observed between the changes in isometric squat performance and the associated change in CMJ output variables at the immediately post time point (Table 1). These observations further highlight the uniqueness and independent nature of the variables.

In functional terms, the changes observed immediately post can be described as compromised SSC function. Although several explanations have been proposed, the main aspect that augments SSC function is the attainment of a high level of force just before the concentric phase begins (15, 16). The decrease observed was brought about initially by unloading to a lesser degree, that subsequently results in a lower velocity of downward movement being achieved and then ultimately not being capable of producing high rates of force development

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toward the latter portion of the eccentric phase. This scenario will correspond with reduced output in the concentric phase; namely, force, velocity and power. The ability of the muscular system to generate force is governed by a combination of neural drive from central nervous system and peripheral contractile function. The variability in functional performance changes after fatiguing exercise can potentially originate with changes either in the central and/or peripheral systems (27). The physiological mechanisms that determine such patterns of fatigue were not directly measured in the current study, however the decrements immediately post exercise appear to be partly caused by changes in muscle contractile function (Table 2 and Figure 1). These changes are often referred to as metabolic fatigue (41). In addition to this type of peripheral fatigue, the concomitant existence of reduced neural drive (20), which has a tremendous influence on the ability to exert force rapidly (1), should also be considered.

On the basis of the CMJ temporal phase analyses, it appears that acute fatigue will not only alter the standard output related variables but can also bring about changes in the shape of the power-, force-, velocity-, and displacement-time curves (Figure 2). The significant changes in the temporal phase analysis very much paralleled those from the peak and instantaneous related variables; however, they do provide an excellent visual representation of the jumps that can be used to examine the nature and precise timing of the fatigue induced changes. In addition, changes in the shape of force-time curves, which are not always evident in standard variables, are potentially the foundation for changes in power, velocity and displacement (14). It is therefore recommended that future fatigue studies should move beyond the standard methodology used and implement this comprehensive form of analysis. These high resolution (477 - 640 Hz) curves may help provide a better understanding of the acute neuromuscular response to resistance loading and offer some insight into the mechanisms that drive the chronic adaptations to training (14, 16). Interestingly, the temporal pattern

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immediately post exercise inversely tracks the observations made after both strength and power training (15, 16). When considering the ensuing early recovery phase post exercise, partial or even full recovery is frequently observed after 1-2 hours (37). This short-term recovery pattern seems to follow the production and clearance of metabolic markers, such as blood lactate, and markers of the development of an inflammatory reaction in response to muscle damage, such as interleukin 6 (19). The subsequent phase of the recovery cycle is typically then characterised by a secondary longer lasting decline in function, the mechanisms responsible for such changes are associated with inflammatory, neural and remodelling processes (19, 23).

The results of the current study indicate that after implementing a high intensity squat protocol, CMJ performance will be impaired for at least 48h post exercise (Table 2). Isometric strength, although severely compromised immediately post exercise, showed a rapid recovery thereafter with no significant impairment at 48h post exercise (Figure 1). A decrease in MVC is widely accepted as a valid marker of exercise-induced muscle damage; however, there is a large inter- and intra-individual variation in the response exercise-induced muscle damage, even when subjects are exposed to standardized exercise protocols (18, 28). Although the factors contributing to this phenomenon have been extensively investigated (40), they remain poorly understood and this may explain much of the divergent findings (9, 26, 44). Collectively, these results indicate different temporal patterns of recovery between MVC and CMJ performance. In the context of sports performance, these findings may be important as the ability to rapidly produce force is paramount when compared to maximal force. Additionally, a compromised ability to produce force rapidly may also increase the risk of sustaining an anterior cruciate ligament injury (51). This information therefore needs to be acknowledged when planning and prescribing the training load of athletes.

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The physiological mechanisms that can potentially explain the pattern of fatigue were not directly measured in the current study. Nonetheless, it is recognised that type II fibres are more susceptible to exercise induced muscle damage and will undergo a greater degree of remodelling that can temporarily impair explosive movements (20). This assertion is supported when we consider the time available to produce force during the two activities (2), with a CMJ performance being heavily influenced by the rate of force development (34). It should however be acknowledged that the symptoms of muscle damage will be markedly reduced in trained athletes, a protective adaptation known as the repeated bout effect (38) and are dependent on the specific muscle group (11). As well as fibre type specific remodelling, another proposed mechanism for a slower recovery of CMJ performance may relate to reduced neural drive (20), which as previously stated has a tremendous influence on the ability to exert force rapidly (1).

PRACTICAL APPLICATIONS

A typical resistance training session can induce a substantial decline in muscle function, as measured using an MVC and CMJ. Coaches should appreciate that these two measures reflect independent qualities and that their recovery pattern may follow different time lines. Complete recovery of the ability to rapidly produce force may require more than 2 days and individual responses should be monitored to help plan acute and chronic training loads. Although a discrete variable such as peak velocity can prove useful when monitoring fatigue, large amounts of data are left unused and therefore subtle changes in phases of the CMJ can't be identified. It is recommended that coaches should move beyond the standard methodology

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used to analyse CMJ performance and implement temporal phase analyses to consider the power-, force-, velocity-, and displacement-time curves.

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Figure 1.

Fatigue induced changes in isometric squat performance. * Significant ($P \leq 0.05$) difference between baseline and immediately post.

Figure 2.

Fatigue induced changes in the power-time (A), force-time (B), velocity-time (C), and displacement (D) curves for the countermovement jump. Normalised time represents the time from the start of the jump to take-off for power and force (A & B) and from the start of the jump to the apex of the jump (C & D). * Significant ($P \leq 0.05$) difference between baseline and immediately post. § Significant ($P \leq 0.05$) difference between baseline and both immediately post and 48h post.

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TABLE 1. Correlations between MVC and CMJ output variables at baseline and their associated relative magnitude of change over time.

	Isometric Squat ($N \cdot kg^{-1}$)	Δ_{IP} Isometric Squat (%)	Δ_{48h} Isometric Squat (%)
Isometric Squat ($N \cdot kg^{-1}$)	1.000		
Peak Concentric Power ($W \cdot kg^{-1}$)	0.628§		
Average Concentric Power ($W \cdot kg^{-1}$)	0.705§		
Peak Concentric Force ($N \cdot kg^{-1}$)	0.632§		
Average Concentric Force ($N \cdot kg^{-1}$)	0.563*		
Peak Velocity ($m \cdot s^{-1}$)	0.526*		
Jump Height (m)	0.556*		
Δ_{IP} Isometric Squat (%)		1.000	
Δ_{IP} Peak Concentric Power (%)		0.154	
Δ_{IP} Average Concentric Power (%)		0.181	
Δ_{IP} Peak Concentric Force (%)		-0.101	
Δ_{IP} Average Concentric Force (%)		0.054	
Δ_{IP} Peak Velocity (%)		0.102	
Δ_{IP} Jump Height (%)		0.147	
Δ_{48h} Isometric Squat (%)			1.000
Δ_{48h} Peak Concentric Power (%)			0.300
Δ_{48h} Average Concentric Power (%)			0.330
Δ_{48h} Peak Concentric Force (%)			0.162
Δ_{48h} Average Concentric Force (%)			0.398
Δ_{48h} Peak Velocity (%)			0.386
Δ_{48h} Jump Height (%)			0.414

$\Delta_{IP =}$ change immediately post relative to baseline; $\Delta_{48h =}$ change at 48h relative to immediately post. § denotes $P < 0.01$; $^*P < 0.05$.

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TABLE 2. Fatigue induced changes in countermovement jump performance.

Variable	Baseline	Immediately Post	48h Post
Power			
Peak Concentric Power ($W \cdot kg^{-1}$)	56.4 ± 8.1	52.7 ± 7.5*	53.7 ± 8.0*
Average Concentric Power ($W \cdot kg^{-1}$)	31.4 ± 4.7	28.5 ± 4.9*	30.0 ± 4.1*
Peak Eccentric Power ($W \cdot kg^{-1}$)	-22.9 ± 4.6	-20.4 ± 4.3*	-22.1 ± 4.3
Average Eccentric Power ($W \cdot kg^{-1}$)	-6.1 ± 1.2	-5.7 ± 1.0	-6.1 ± 1.0
Force			
Peak Concentric Force ($N \cdot kg^{-1}$)	26.7 ± 3.4	25.3 ± 3.2*	26.5 ± 2.9
Average Concentric Force ($N \cdot kg^{-1}$)	21.0 ± 2.2	20.0 ± 2.2*	20.6 ± 1.9
Peak Eccentric Force ($N \cdot kg^{-1}$)	26.0 ± 3.6	23.8 ± 3.9*	25.6 ± 3.3
Minimum Eccentric Force ($N \cdot kg^{-1}$)	1.0 ± 0.6	1.5 ± 1.1*	1.2 ± 0.6
Velocity			
Peak Velocity ($m \cdot s^{-1}$)	2.82 ± 0.26	2.70 ± 0.26*	2.74 ± 0.24*
Minimum Velocity ($m \cdot s^{-1}$)	-1.44 ± 0.19	-1.36 ± 0.17*	-1.40 ± 0.17
Displacement			
Jump Height (m)	0.361 ± 0.078	0.324 ± 0.074*	0.338 ± 0.072*
Minimum Displacement (m)	-0.304 ± 0.073	-0.301 ± 0.064	-0.296 ± 0.062

* Significant ($P \leq 0.05$) difference from baseline.

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Figure 1.

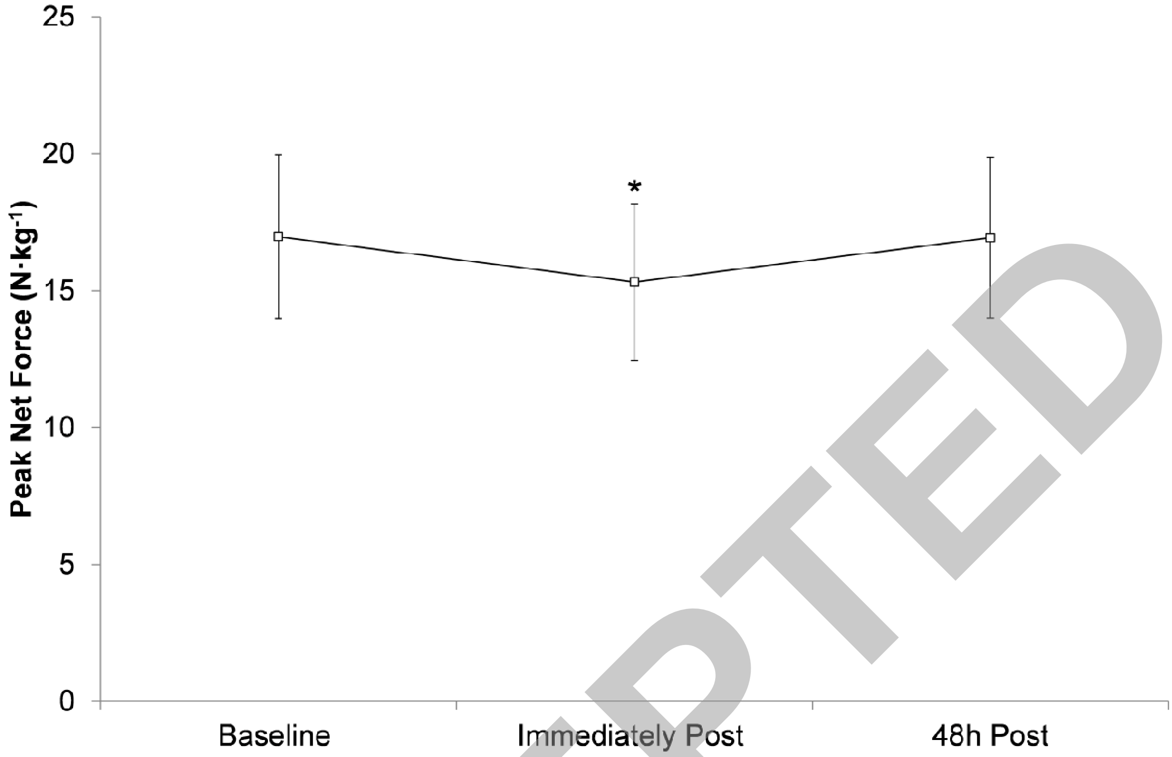

Figure 2.

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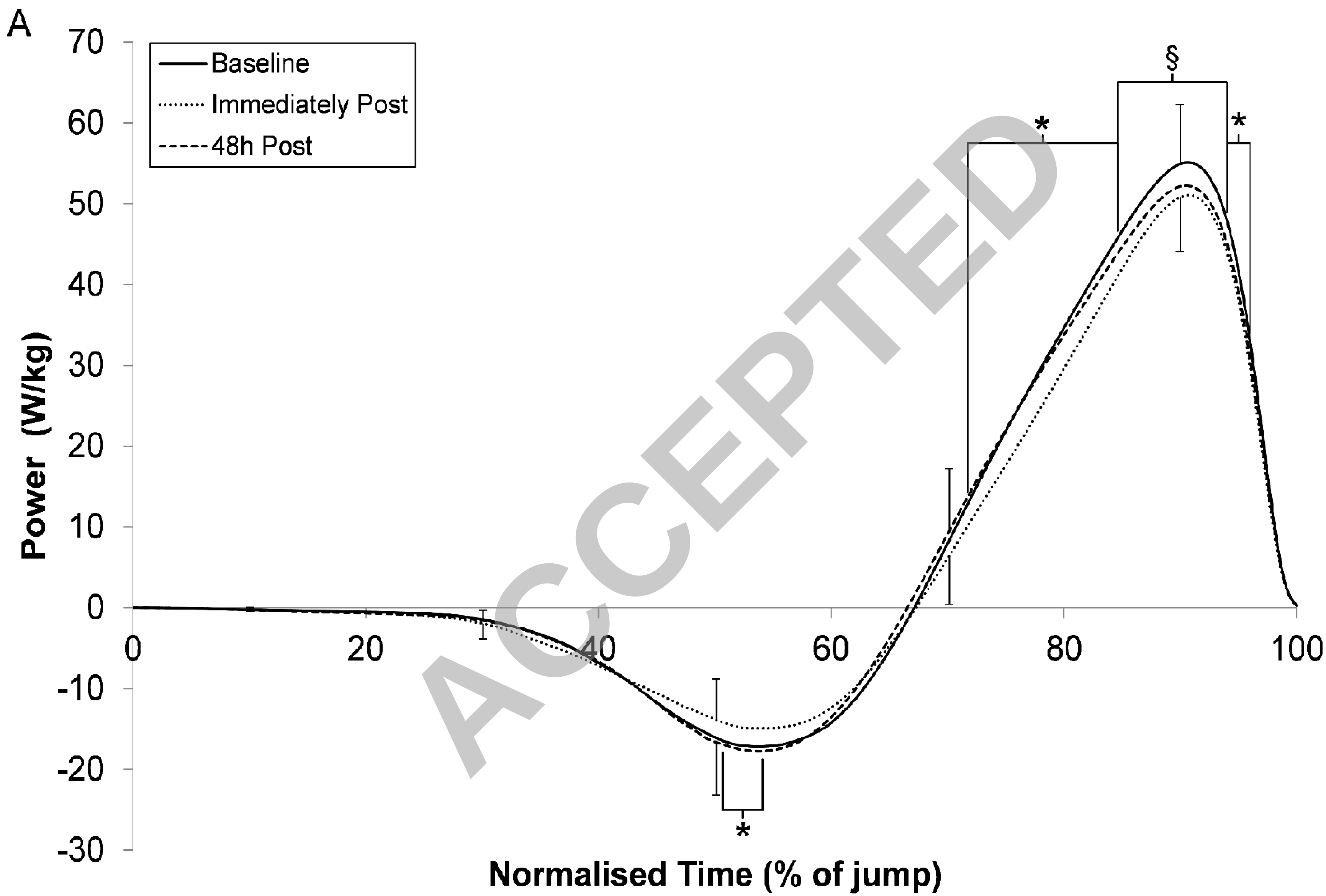

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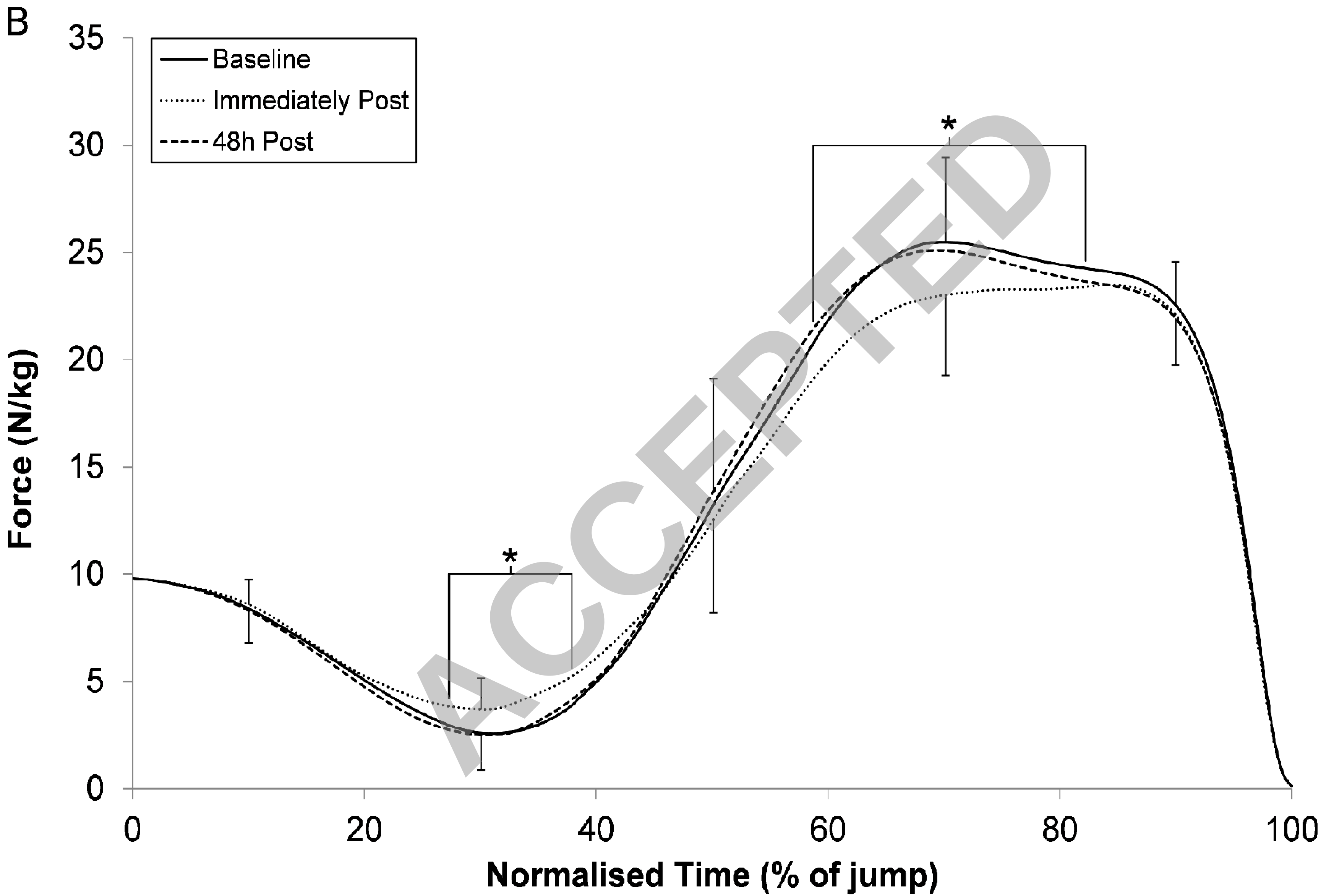

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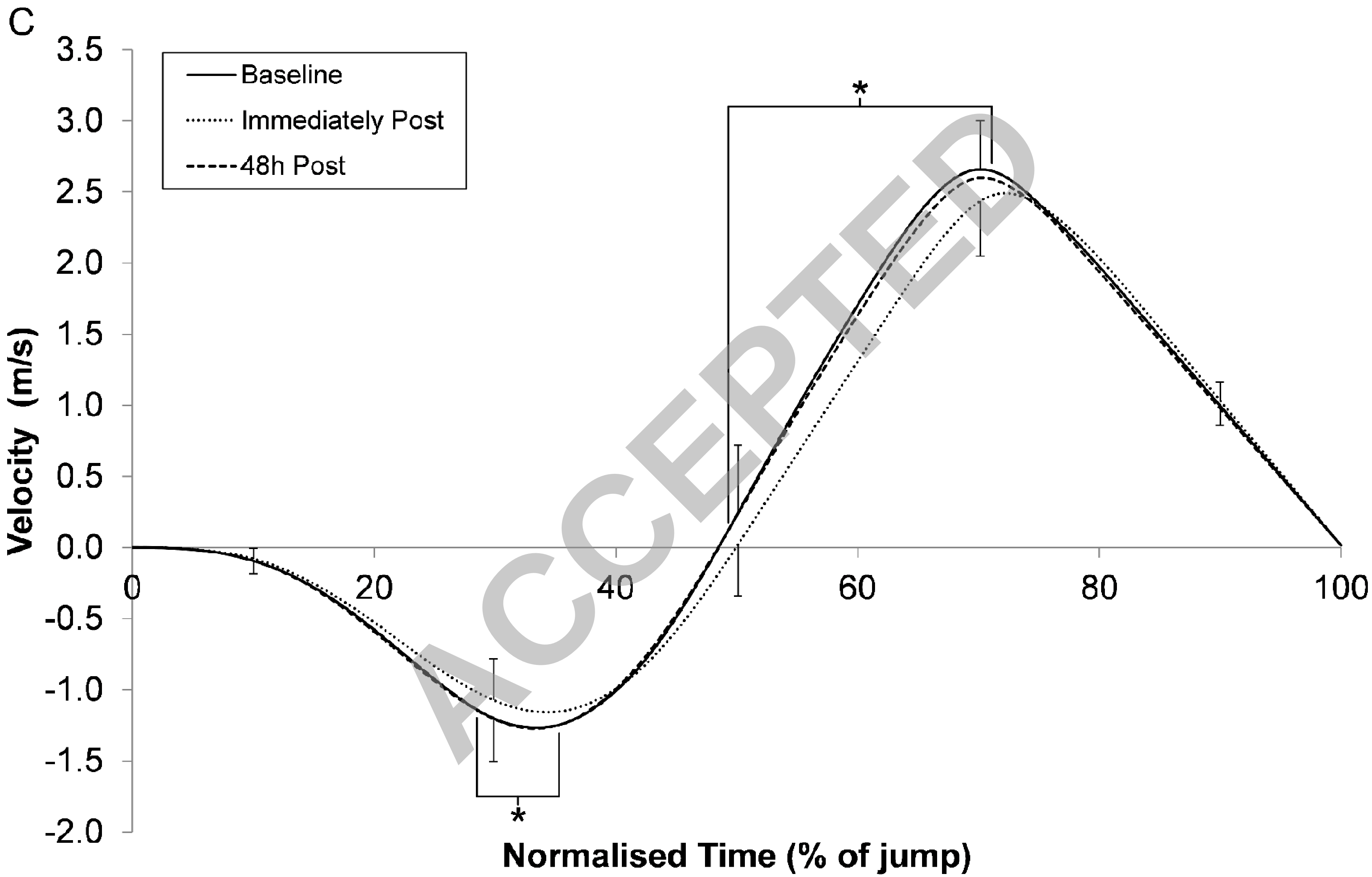

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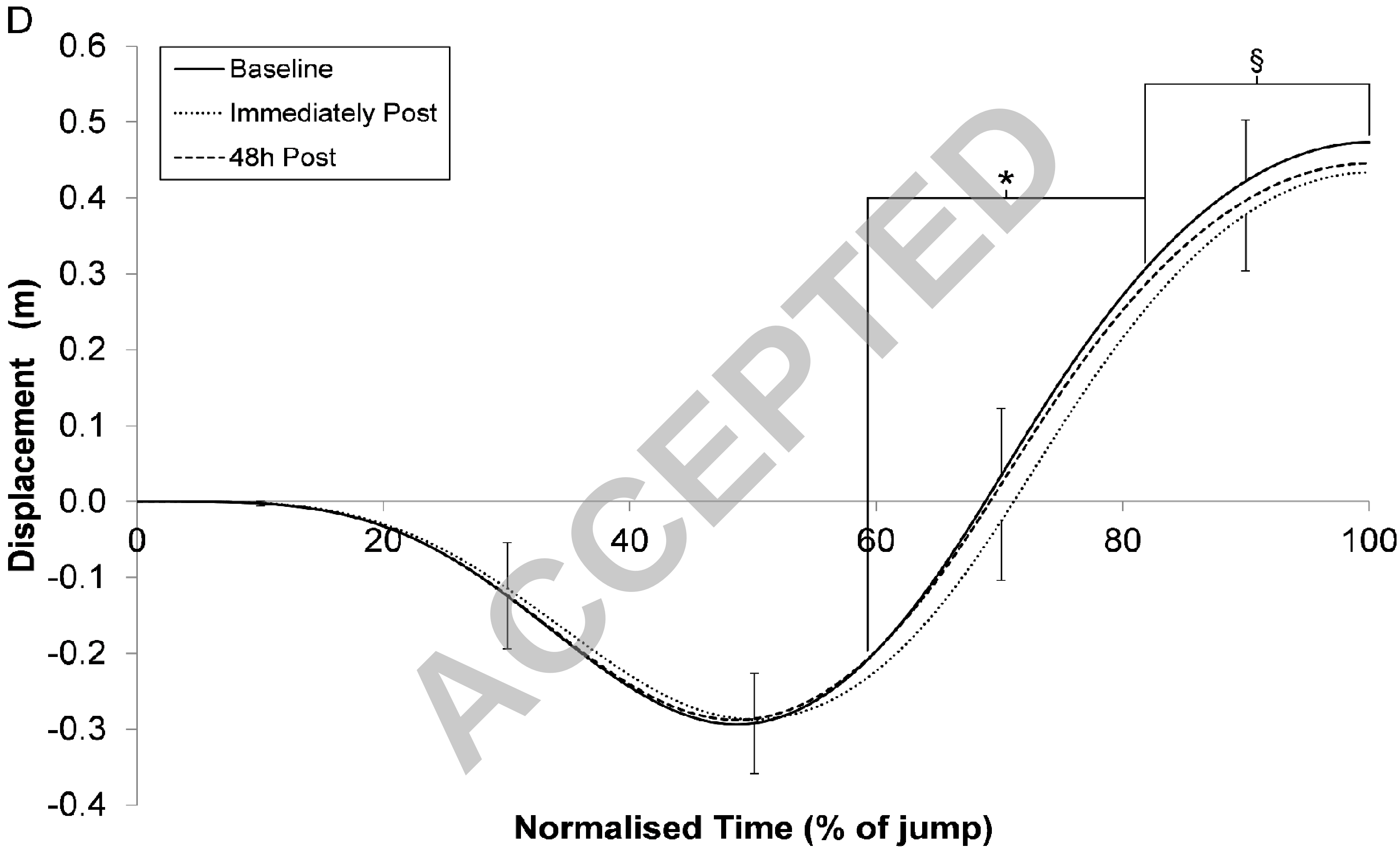

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